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A Cold-Bend Test for Thermoplastic Cable Jackets

Pennsylvania State Univ, University Park

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A COLD-BEND TEST FOR THERMOPLASTIC CABLE JACKETS

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A very simple cold-bend test was devised and tested for evaluating thermoplastic jackets used on mine-power-feeder cables. A test sample is bent into a semicircle whose radius is equal to the minimum bend radius recommended by IPCEA and then cooled to the desired test temperature (-35° C). While at temperature, the sample is straightened by pulling the cable ends with a winch arrangement. The results show that of the jackets tested, those which cannot withstand the test literally burst when the sample is straightened.

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This technical report has been reviewed and approved.

CERTIFICATIONS OF THE ABSENCE OF PATENTS AND INVENTIONS

This statement certifies that at the grant report date, no inventions have been developed from Grant G0155197. Consequently, no patents are pending.

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DISCLAIMER NOTICE

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A COLD-BEND TEST FOR CABLE JACKETS

INTRODUCTION

There are a number of test procedures which can be followed to evaluate a cable's resistance to failure when bent at low temperatures — IPCEA-NEMA, MIL-C-13777G, and Federal Test Method Standards (1, 2, 3). In each of these methods the cable is cooled to the test temperature while it is straight, and then it is bent around a mandrel to determine if the components can withstand the stresses which are created. In practice, however, the opposite type of bending can be the case. With mine-power-feeder cables, for example, the cable is often stored out-of-doors on the shipping spool or looped in an oval or figure-eight pattern on a flat car or skid. With low-temperature weather conditions, the cable "freezes" in the bent condition and may not have sufficient time to "thaw" before it is straightened in the process of installation. Straightening can sometimes cause damage to the cable components, especially to thermoplastic jackets as recently experienced in at least one coal mine in Pennsylvania when outside temperaturs dipped to $-35^{\circ}C$ (4). In order to evaluate cable jacket performance under similar conditions, a simple cold test was devised and evaluated. In this test, the sample is first bent into a curve of given radius: cooled to the test temperature of $-35^{\circ}C$; and then pulled straight.

Funding for this work was provided by the U. S. Bureau of Mines at the request of Mr. John Pringle, Department of Deep Mine Safety, Pennsylvania Department of Environmental Resources. Mr. George Conroy of the U. S. Bureau of Mines was the Technical Project Officer.

TEST METHOD

The test method does not use a mandrel but instead the cable is bent into a semi-circular arc using a scribed line as the bending guide, Figure 1. The radius of the bend is the same as the minimum bend radius specified by IPCEA for the particular cable to be tested. The cable's mean diameter is used in making the calculations and the sample length is equal to half a circle of Π times the minimum bend radius recommended by IPCEA.

Nylon webbing is attached to both ends of the cable as shown in Figure 2 to help provide a means for pulling the sample straight after cooling. The webbing is attached with a hose clamp and a small circumferential gap is made in the jacket covering, so that the clamp does not restrain the jacket movement when the sample is bent.

A dry-ice cold box was used for cooling the cable sample to the test temperature although other cooling methods could be just as effective. The cold box is shown in Figures 3 through 6. It consists of a bottom section which holds the test sample, a middle section with screened bottom for the dry ice, and the covers. A partial cross-sectional view of the box construction is shown in Figure 7.

A hand-cranked winch is used to pull the cable straight while it is at the test temperature and still in the cold box. The winch arrangement is seen in Figure 3. Other methods such as a constant-speed motorized winch could be substituted.

Sample temperature is monitored using copper constantan thermocouples and a multi-channel recorder. One thermocouple is attached to the cable jacket's outer surface and another is placed inside a dummy

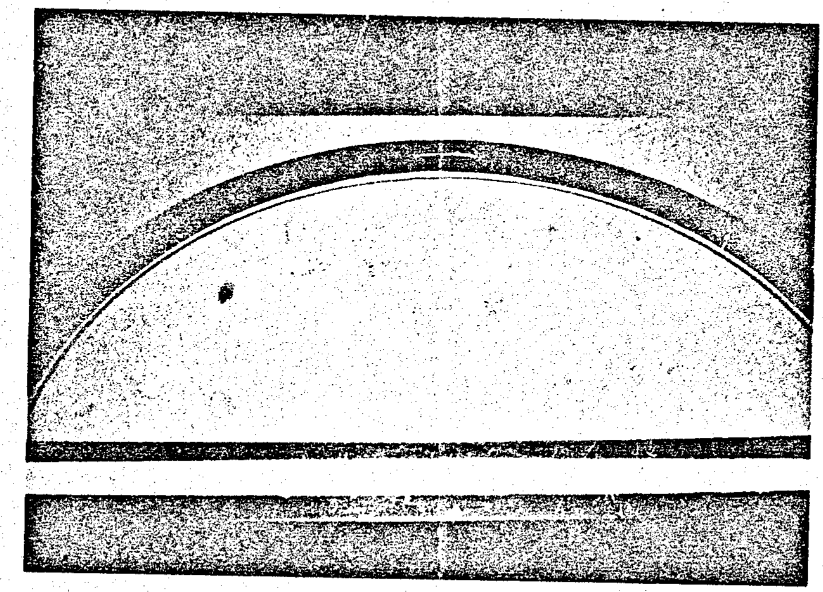

Figure 1. Cable Sample Bent in Semi-circle along Scribed Line.

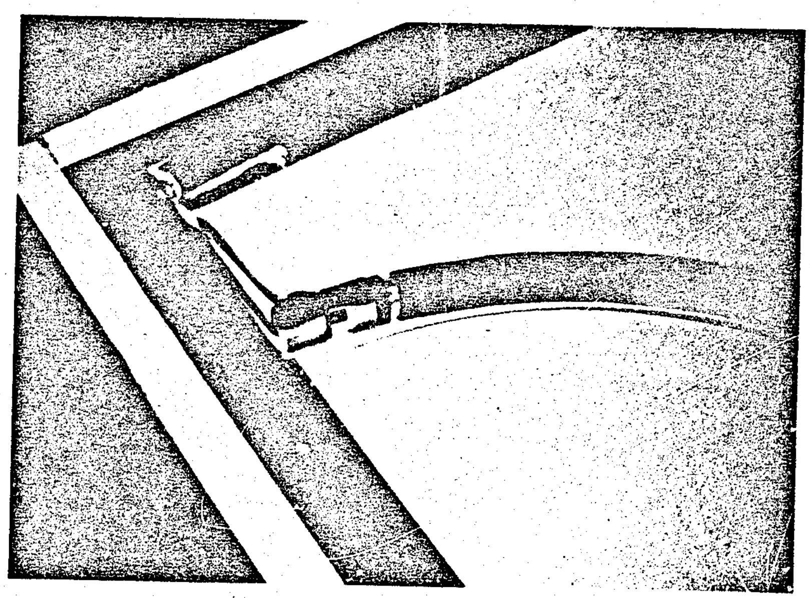

Figure 2. End Attachment for Straightening Cable.

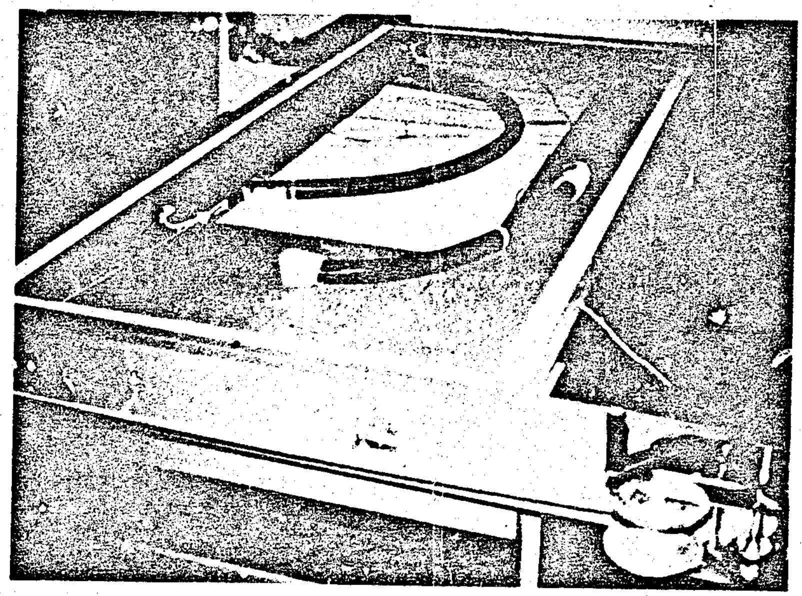

Figure 3. End View of Cold Box Showing Cable Samples and Winch.

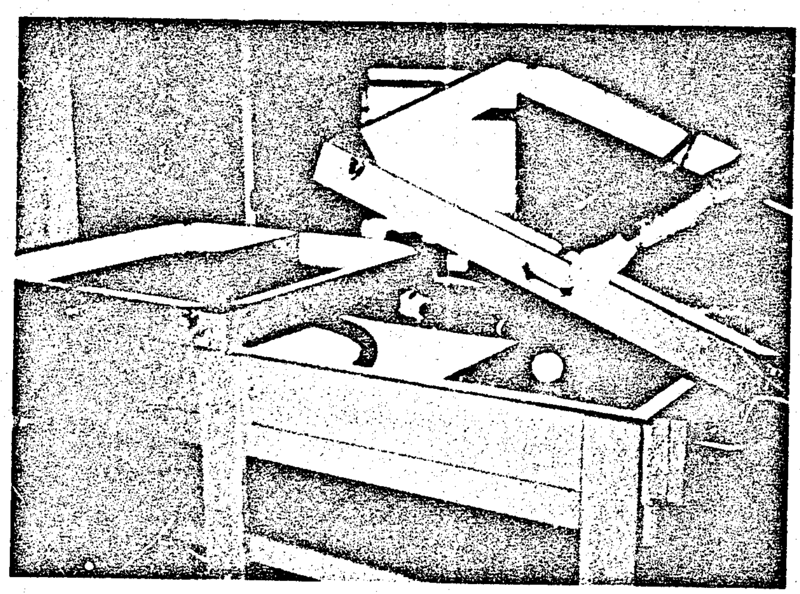

Figure 4. Side view of Cold Box Showing Dry-Ice Compartments.

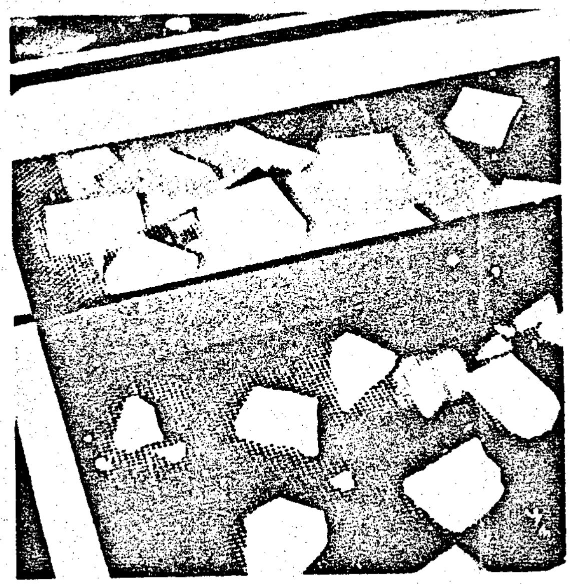

Figure 5. Dry Ice in Place.

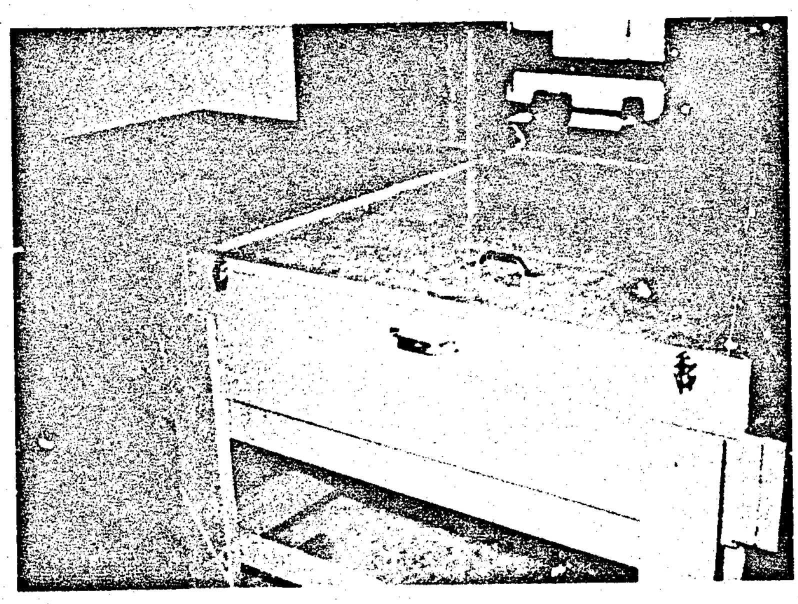

Figure 6. Complete Cold Box With Insulated Covers.

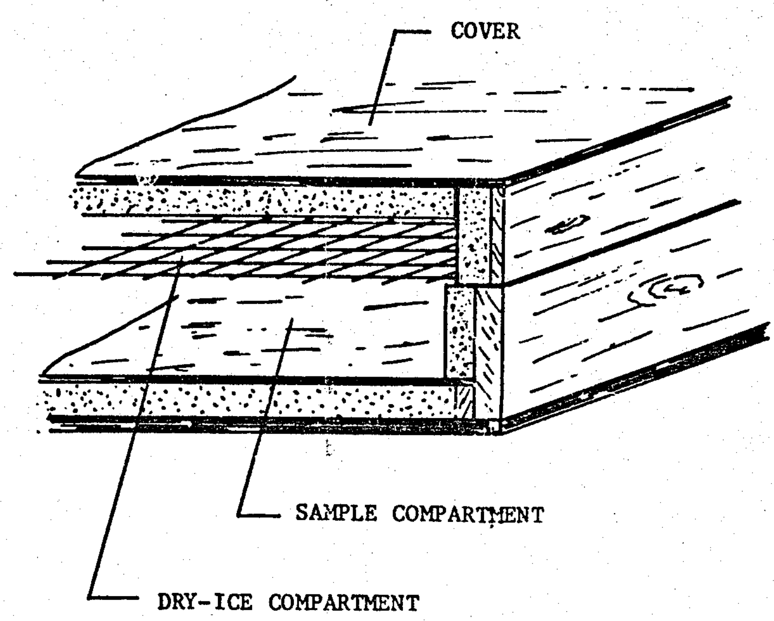

Figure 7. Cold Box Construction

sample in one of its phase conductors. This is done to provide an approximate indication of the temperature spread within the test sample and shows the thermal lag between the inside and outside parts of the cable. A third thermocouple is used to monitor the air temperature in the general vicinity of the sample.

The cold box has no provisions for regulating temperature once it is loaded with the dry ice and closed. However, with a little experimentation, the sample can be easily cooled to the desired temperature for testing. Typical cooling curves for test runs are shown in Figures 8 and 9. The air temperature is the quickest to drop followed by the cable surface temperature and then the conductor temperature. In Figure 8, the cable temperatures bottom near $-35^{o}C$. At this point the sample can be pulled straight and the test is completed.

In Figure 9, the air and surface temperatures overshoot the $-35^{o}C$ mark but then begin to rise and eventually all three temperatures are within 1 or $2^{o}C$ of the desired temperature. At this point the sample can be tested.

The rises in temperature after the cold box is opened (Figures 8 and 9) is an indication of how quickly the cable jacket might warm up if it were removed from the cooling chamber for testing.

Both the minimum temperatures and the cooling rates were a function of the amount of ice and its distribution in the cold box. Twenty-five pounds of ice distributed as shown in Figure 5 was typical for the tests conducted here.

All samples tested here were straightened in less than a minute using the winch.

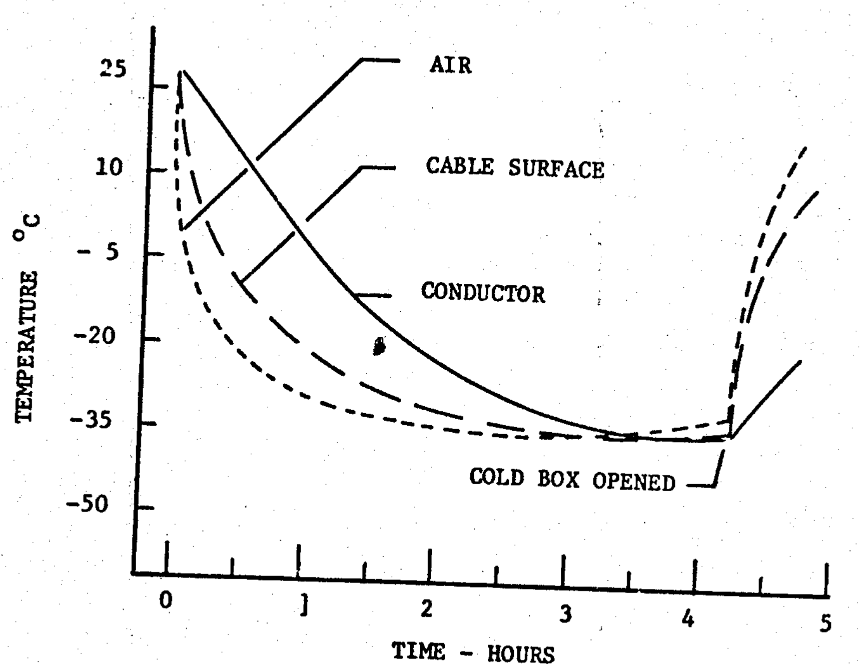

Figure 8. Cable Cooling Curves Leveling near -35° C.

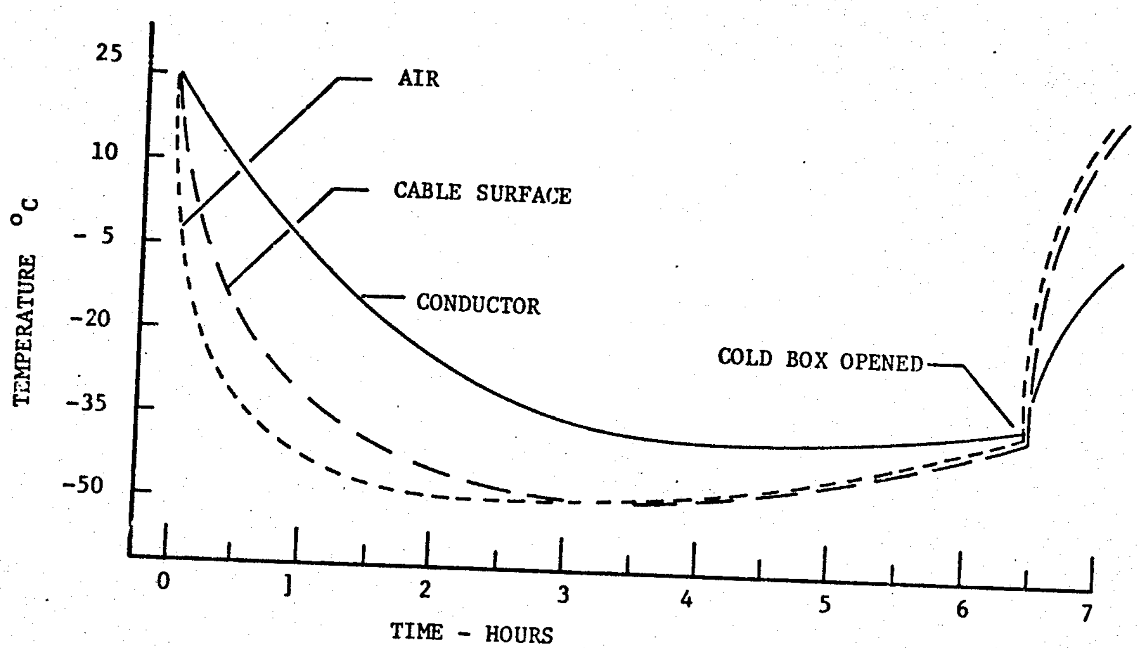

Figure 9. Cable Cooling Curves Showing Temperature Overshoot to -50° C.

TEST RESULTS

The cold-bend test was tried on a number of different mine-power-feeder cables having a conductor sizes of 2 and 4/0 AWG. Those which withstood the test showed no signs of jacket failure. For those which failed, the jackets literally burst as the cable was straightened. An example of a failed cable is shown in Figure 10. An unfailed sample is shown in Figure 11.

A brief draft procedure for using this test method for evaluating cable jacket performance at low temperatures is presented in Appendix A of this report. It is recommended that this type of test be used in conjunction with the flame resisting test normally required for MSHA and Pennsylvania approval.

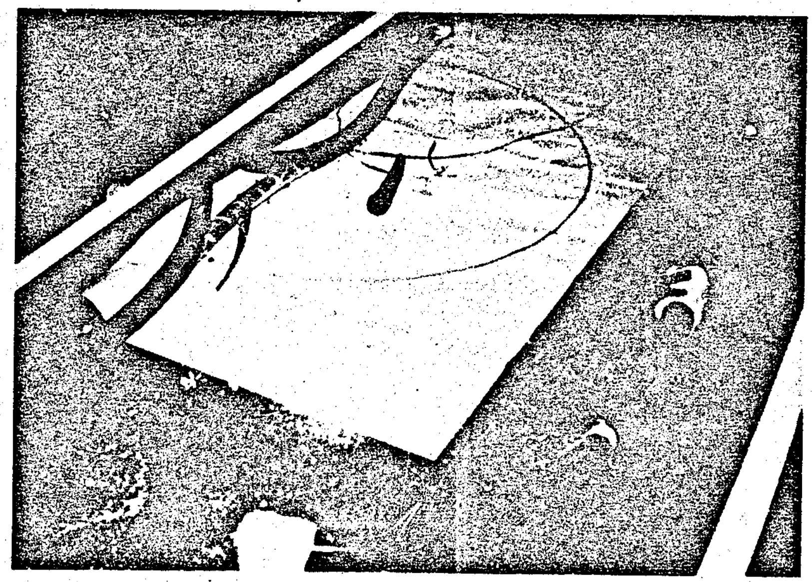

Figure 10. Example of Broken Cable Jacket.

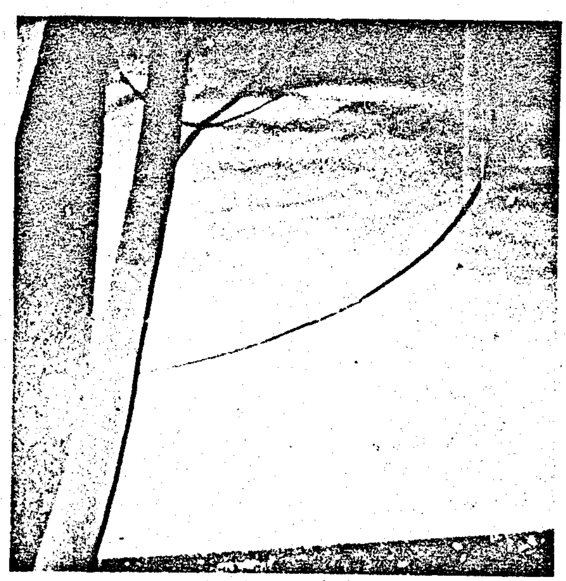

Figure 11. Cable Jacket that Withstood the Cold Bend Test.

REFERENCES

1. Insulated Power Cables Engineers Association, IPCEA-NEMA Standards Publication, Rubber-Insulated Wire and Cables for the Transmission and Distribution of Electrical Energy, IPCEA Pub. No. S-19-81 (Fifth Edition), NEMA Pub. No. WC 3-1969, October, 1975.

2. United States Department of Defense Military Specification MIL-C-13777G, "Cables, Special Purpose, Electrical: General Specification for," February, 1976.

3. United States Federal Government, Federal Test Method Standard No. 228, "Cable and Wire, Insulated; Methods of Testing," April 1967.

4. Pringle, John, Department of Deep Mine Safety, Pennsylvania Department of Environmental Resources, Personal Communication, August, 1977.

APPENDIX A

Proposed Cold-Bend Test for Cable Jackets

1.0 Scope

1.1 This test shall be used to determine a cable jackets' ability to withstand bending at low temperatures.

2.0 Specimen

2.1 Each test specimen shall be a piece of finished cable equal in lenght to Π time the minimum bend radius specified in paragraph 4.2.

2.2 Prior to testing, the test specimen shall be free from all mechanical damage.

3.0 Apparatus

3.1 The apparatus shall consist of a cold chamber for cooling the specimen to the required temperature, within ±2^{o}C, and provision for straightening the specimen within the chamber while at temperature.

4.0 Procedure

4.1 The cable specimen shall be bent so that its inside radius conforms to a semi-circle of radius equivalent to that determined in paragraph 4.2. The test specimen shall be bent while at room temperature (23^{o}C ± 2^{o}C).

4.2 The radius of bend for the specimen shall be the minimum bend radius recommended by IPCEA-NEMA Standards Publication for Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (IPCEA Pub. No. S 19-81,

4.2 - continued

NEMA Pub. No. WC3 Appendix N).

4.3 The specimen shall be cooled to the temperature of $-35 \pm 2^{\circ}C$.

4.4 The specimen shall be straightened while at the specified test temperature. The straightening shall be done at a uniform rate and shall require no less than half a minute and no more than one (1) minute from start to finish.

4.5 Methods used to make attachments to the ends of the specimen for pulling the cable straight shall not restrict the movement of the cable jacket as it is bent. (A satisfactory method of attachment is illustrated in Figure 2).

4.6 After the specimen has been straightened, it shall be visually examined for defects in the cable jacket. Any cracks or breaks which have developed as a result of the straightening while at the cold temperature shall be reason for failure. Unaffected jackets shall be considered to have passed the test.

5.0 Test Facility

For a limited time, a facility for performing the above test will be maintained at the Pennsylvania State University, Department of Mineral Engineering. Construction prints for the apparatus may be requested from:

George J. Conroy
U.S. Bureau of Mines, PMSRC
4800 Forbes Avenue
Pittsburgh, Pa. 15213
Tel. 412-892-2400

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